Units, Physical Quantities, and Vectors

Goals for Lecture

- To learn three fundamental quantities of physics and the units to measure them
- To keep track of significant figures in calculations
- To understand vectors and scalars and how to add vectors graphically
- To determine vector components and how to use them in calculations
- To understand unit vectors and how to use them with components to describe vectors
- To learn two ways of multiplying vectors

What is Physics

Physics is an experimental science in which physicists seek patterns that relate the phenomena of nature.

- The patterns are called $\boxed{\text{physical theories}}$.
- A very well established or widely used theory is called a $\boxed{\text{physical law}}$ or $\boxed{\text{principle}}$.

Standards and units

- Length, time, and mass are three fundamental quantities of physics.
- The International System (SI for Système International) is the most widely used system of units.
- In SI units, length is measured in *meters*, time in *seconds*, and mass in *kilograms*.

Unit prefixes

The Prefixes Used with SI Units

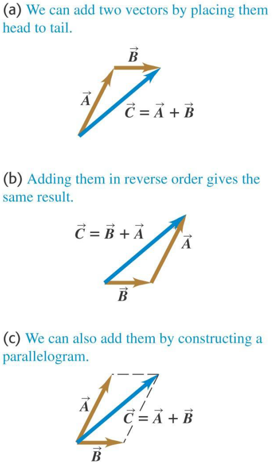
Prefix	Symbol	Meaning	Scientific Notation
exa-	E	1,000,000,000,000,000,000	10^{18}
peta-	P	1,000,000,000,000,000	10^{15}
tera-	T	1,000,000,000,000	10^{12}
giga-	G	1,000,000,000	10^{9}
mega-	M	1,000,000	10^{6}
kilo-	k	1,000	10^{3}
hecto-	h	100	10^{2}
deka-	da	10	10^{1}
—	—	1	10^{0}
deci-	d	0.1	10^{-1}
centi-	c	0.01	10^{-2}
milli-	m	0.001	10^{-3}
micro-	μ	0.000 001	10^{-6}
nano-	n	0.000 000 001	10^{-9}
pico-	p	0.000 000 000 001	10^{-12}
femto-	f	0.000 000 000 000 001	10^{-15}
atto-	a	0.000 000 000 000 000 001	10^{-18}

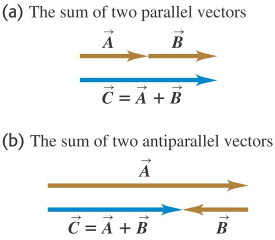
Vectors and scalars

- A scalar quantity can be described by a *single number*.
- A vector quantity has both a *magnitude* and a *direction in space*.
- A vector quantity is represented in italic type with an arrow over it: $\vec{A}$.
- The magnitude of $\vec{A}$ is written as A or $|\vec{A}|$.

Adding two vectors

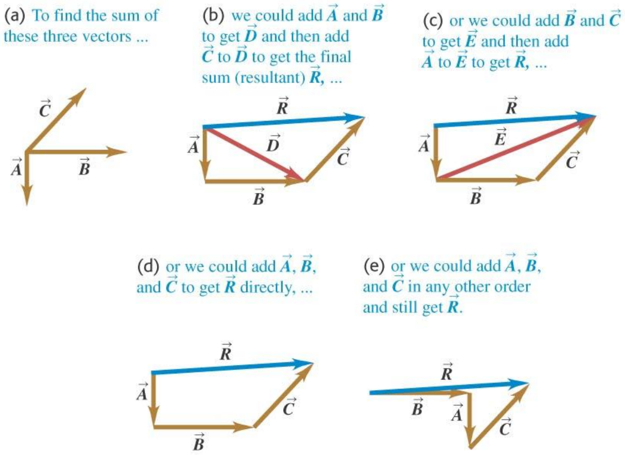
Two vectors may be added graphically using either the parallelogram method or the head-to-tail method.



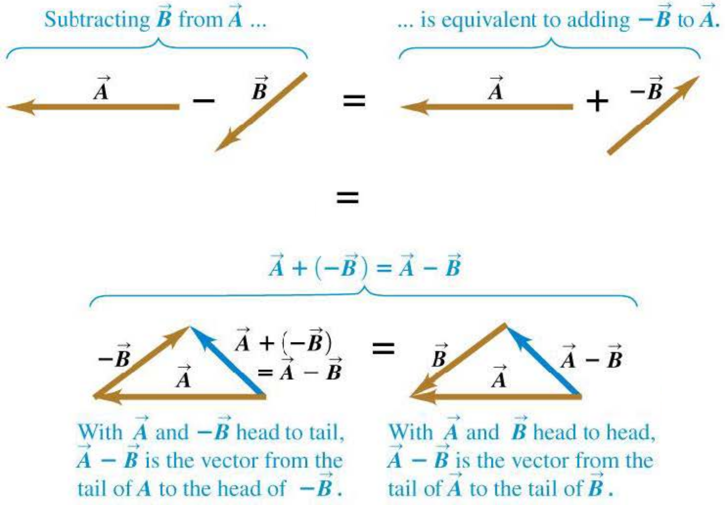


Adding more than two vectors graphically

To add several vectors, use the head-to-tail method.

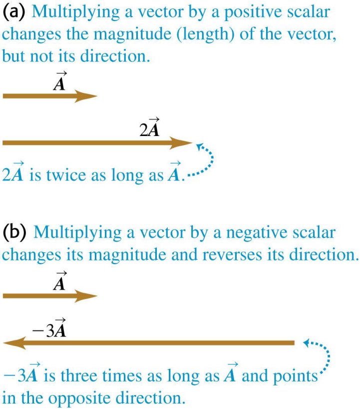


Subtracting vectors



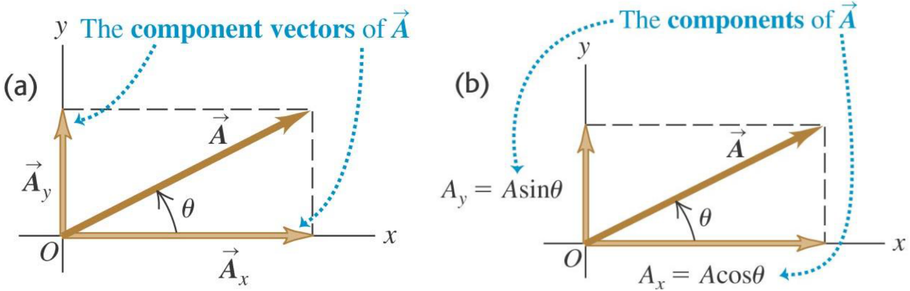
Multiplying a vector by a scalar

If c is a scalar, the product $c\vec{A}$ has magnitude cA.



Components of a vector

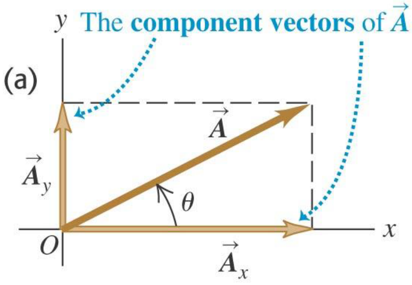
1. Adding vectors graphically provides limited accuracy. Vector components provide a general method for adding vectors.
2. Any vector can be represented by an x-component A_x and a y-component A_y.
3. Use trigonometry to find the components of a vector: $A_x = A\cos\theta$ and $A_y = A\sin\theta$, where θ is measured from the $+x$-axis toward the $+y$-axis.

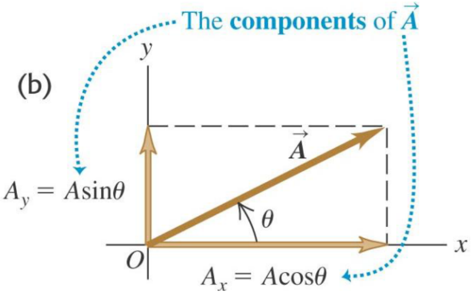


Magnitude and components of the vector

We can use the components of a vector to find its magnitude and direction:

$$\boxed{A = \sqrt{A_x^2 + A_y^2}}, \quad \boxed{\tan\theta = \frac{A_x}{A_y}}$$

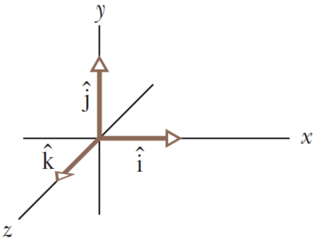




Unit vectors

1. A unit vector has a magnitude of 1 with no units.
2. The unit vector $\vec{i}$ points in the $+x$-direction, $\vec{j}$ points in the $+y$ -direction, $\vec{k}$ points in the $+z$-direction.
3. Any vector can be expressed in terms of its components as

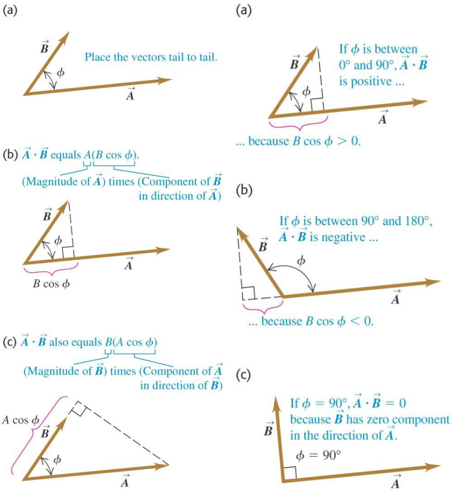
$$\boxed{\vec{A} = A_x\vec{i} + A_y\vec{j} + A_x\vec{k}}$$



The scalar product

The scalar (or dot) product of two vectors $\vec{a}$ and $\vec{b}$ is written as $\vec{a} \cdot \vec{b}$ and is the scalar quantity given by:

$$\boxed{\vec{a} \cdot \vec{b} = ab\cos\varphi}$$



The scalar product via components

In terms of components the scalar product can be calculated as:

$$\boxed{\vec{a} \cdot \vec{b} = a_x b_x + a_y b_y + a_z b_z}$$

The vector product

The vector (or cross) product of two vectors $\vec{a}$ and $\vec{b}$ is written as $\vec{a} \times \vec{b}$ and is the vector whose magnitude is given by:

$$\boxed{|\vec{a} \times \vec{b}| = ab \sin\varphi}$$